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PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(c).

Docket Number	6270/117	Type a plus sign (+) inside this box	+

INVENTOR(S)/APPLICANT(S)			
Last Name	First Name	Middle Initial	Residence (City And Either State Or Foreign Country
Gunn	Colin	N.	Victoria, BC, V9B 3K5, Canada
Lightbody	Simon	H.	Victoria, BC, V8Z 5T9, Canada
Forth	J.	Bradford	Victoria, BC, V8S 2H9, Canada
Hancock	Martin	A.	Victoria, BC, V8X 3S8, Canada

TITLE OF INVENTION (280 characters max)

BODY CAPACITANCE ELECTRIC FIELD POWERED AC LINE SENSING SYSTEM

CORRESPONDENCE ADDRESS

James L. Katz
Brinks Hofer Gilson & Lione
P.O. Box 10395
Chicago

STATE	IL	ZIP CODE	60610	COUNTRY	USA

ENCLOSED APPLICATION PARTS (check all that apply)

☒ Specification	Number of Pages	14	☐ Small Entity Statement
☒ Drawing(s)	Number of Sheets	1	☐ Other (specify) ____

METHOD OF PAYMENT (check one)

☐ A check or money order is enclosed to cover the Provisional filing fees. ☒ The Director is hereby authorized to charge any deficiency in the filing fees or credit any overpayment to Deposit Account Number **23-1925**	PROVISIONAL FILING FEE AMOUNT(S)	$160.00

The invention was made by an agency of the United States Government or under a contract with an Agency of the United States Government.

☒ No.
☐ Yes, the name of the U.S. government agency and the Government contract number are:_____.

Respectfully submitted,

SIGNATURE: ____________ Date: 7/25/03
TYPED OR PRINTED NAME: James L. Katz Registration No. 42,711
(if appropriate)

CUSTOMER NO. 00757 - Brinks Hofer Gilson Lione

☐ Additional inventors are being named on separately numbered sheets attached hereto.

PROVISIONAL APPLICATION FILING ONLY

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
PROVISIONAL APPLICATION FOR UNITED STATES LETTERS PATENT

INVENTORS: Colin N. Gunn
Simon H. Lightbody
J. Bradford Forth
Martin A. Hancock

TITLE: Body Capacitance Electric Field Powered AC Line Sensing System

ATTORNEY: James L. Katz (Reg. No. 42,711)
BRINKS HOFER GILSON & LIONE
POST OFFICE BOX 10395
CHICAGO, ILLINOIS 60610
(312) 321-4200

BODY CAPACITANCE ELECTRIC FIELD POWERED AC LINE SENSING SYSTEM

RELATED APPLICATIONS

[0001]

BACKGROUND

[0002] The present invention relates to high voltage AC power line sensing.

[0003] Typically when it is necessary for a power company to transmit electrical power over long distances, it is transmitted at relatively high voltages. These high voltages are often much higher than the voltages used by customers of the electric power. When a voltage greater than 1 kilovolt (kV) and less than 40kV is used for a particular power line, the power line is typically referred to as a distribution line. When a voltage greater than 40kV is used, the power line is typically referred to as a transmission line. Transmission lines are generally used to transmit larger amounts of power over greater distances that distribution lines.

[0004] When a producer of electric power wants to connect to the electric grid, they can be connected at either distribution line or transmission line level depending on the capacity of the producer's generating plant. Increasingly, due to deregulation in the power industry, the producer's generating plant is not owned by the same company as the transmission and distribution lines the plant will connect to. These types of producers are often referred to as independent power producers (IPPs). Since the power lines and the generating plant are not owned by the same company, it becomes much more important to accurately determine the amount of power the plant is feeding into the electrical grid through the transmission or distribution lines. Even when the generating plant and the power lines are owned by the same company, it is often advantageous to accurately monitor the amount of power being fed into the electrical grid.

[0005] IPPs will often only produce power when the demand for power is such that it is economical to do so. Therefore some IPPs may only produce power for a small percentage of time during a year. When the IPP is not feeding power into the grid, its

generators are normally shut down and the IPP actually draws power from the electrical grid. The amount of power drawn from the grid in this situation is usually much smaller than when the IPP is generating power. A power usage by the IPP of 1000 times less than its power generation capability is quite possible when the plant is idle. The IPP must be accurately billed for the energy they consume during idle periods and accurately compensated for energy generated during active periods.

[0006] It is highly desirable for the energy meter and other instrumentation monitoring the flow of power to and from the producer to accurately measure both the power usage when the producer is idle and the power production when the producer is operating. This means that accurate energy metering and monitoring over a wide dynamic range such as 1000 times is highly desirable. The energy metering and monitoring is often done at grid level voltages. Therefore, the voltage does not vary very much (perhaps by +/-10% of its nominal value). This means that the wide variation in power flow seen by the energy metering and monitoring equipment is primarily due to the variation in current.

[0007] An energy meter capable of measuring over a wide dynamic range of current is described in U.S. Patent Application Serial No. 10/341,079 to Hyatt et al. and entitled "Energy Device with and Extended Dynamic Range on Current Readings" which is hereby incorporated by reference.

[0008] Using an energy meter with a wide dynamic range capability for current is only part of the solution for accurately monitoring the flow of power to and from a producer. Energy meters for this type of application are typically connected through external current and voltage sensors. At least the current sensors themselves should also have a wide dynamic range. Optical current sensors such as those described in the document entitled "OPTICAL TECHNOLOGY: A NEW GENERATION OF INSTRUMENT TRANSFORMER" by Klimek published in Issue 2/2003 of Electricity Today have often provided the largest dynamic range. These sensors are often mounted on large insulator stacks and weigh 100s of kilograms.

[0009] The installation costs for sensors mounted to high voltage transmission lines may often be significant. In fact the installation cost may be more than the cost of the sensor itself in some cases. Some of the reasons for this include the large size and weight of the sensors and the downtime that is experienced when installing, re-installing or

replacing a defective sensor. Most of the weight and size of many of these sensors is the insulator used to isolate the sensor from ground.

[0010] Another consideration that must be taken into account when accurate accounting for energy produced and consumed by a producer is that the instrumentation may have to be regularly calibrated to ensure accuracy. This means that the sensors may be regularly un-installed and sent for calibration while a replacement sensor is installed. This results in the install/re-install costs as well as significant shipping costs due to the weight of the sensors. This recalibration interval may be approximately every three years and the install-reinstall costs for a single sensor may be in the neighborhood of $100,000US.

[0011] Sensors that power themselves off the magnetic field generated by the current flowing through the line they are monitoring are also available. One such device is described in U.S. Patent No. 4,799,005 to Fernandes entitled "Electrical power line parameter measurement apparatus and systems, including compact, line-mounted modules". This device may enable decreased install-reinstall costs, but because it is powered from the magnetic field generated by the current flowing through the line it is measuring, it may not be usable when the line current varies over a wide dynamic range. This is due to the fact that the magnetic field generated at low current may not be adequate to generate enough power to power the device or the CT used to power the device may be too complex or expensive to be practical.

[0012]

SUMMARY

[0013] It is therefore an objective of the present invention to provide a high voltage line mounted sensor. The sensor may have no physical connection to the ground or any other structure at a voltage potential that requires an insulative barrier of a similar size. The sensor is self powered independent of the amount of current flowing through it. The sensor uses a radio frequency (RF) or other wireless means of transmitting information to a ground mounted monitor. The sensor may also provide accurate monitoring of the power line over a wide dynamic range of current.

[0014] The present invention is defined by the following claims, and nothing in this section should be taken as a limitation on those claims.

[0015] Further aspects and advantages of the invention are discussed below in conjunction with the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Figure 1 depicts a cross section of an exemplary sensor of the present invention with both mechanical and electrical elements depicted.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

[0017] The invention relates to self-powered, high voltage transmission line sensor applications. Sensed parameters may include current, line temperature, vibration (due to arcing, corona or other effects), strain/tension (due to ice, wind loading, conductor breakage, tower collapse, etc.), electric-field (which is indicative of the steady state and transient voltage on the line), lightning detection (transient or optical), etc. An important component relates to the power supply energy source means.

[0018] Prior art self-powered transmission line sensors, particularly for current measurement, come in a variety of forms as discussed above employing various transducer topologies and data transmission methods. Being self-powered provides an obvious benefit from an installation and HV isolation standpoint. In many cases the power energy means come from a variety of magnetic field methods whereby power is extracted through magnetic induction; typically through the use of a magnetic core and secondary winding clamped axially about the transmission line conductor. The primary difficulty with these methods is the reliance on sufficient line current required to produce sufficient magnetic field strength over some defined and wide dynamic range. At low line currents, for instance the line magnetization current of an idle IPP generating plant, it would be difficult to provide the energy required to power the sensor and it's associated electronics (microprocessor, RF link, etc). If the line current is below a critical threshold

then the sensor may cease to function completely. One constant is line voltage. It is generally always available and other than in situations such as short lived transients if it disappears then so does the line powering current and therefore, there is no longer a need to measure many of the parameters.

[0019] The invention makes use of the fact that a metallic conducting body (of arbitrary shape) has a Body-to-Earth capacitance through which an electric current can flow. The current and resulting voltage may be electronically converted to current and voltage levels usable for electronic sensor energy requirements without requiring a physical connection between two high voltage potentials which would violate conditions of desirable electrical isolation.

[0020] The diagram depicts the invention in cross section from both a structural and electrical standpoint.

[0021] The cylindrical sensor body 1 is formed from a lightweight conductive metal (such as aluminum) casing having continuous and conductive end pieces 5 distributed radially and axially about a centrally located transmission conductor 10 that extends throughout the cylindrical sensor body 1 and beyond the conductive end pieces 5. The transmission conductor 10 is supported by and extends through two electrically insulating support bushings 15 in such a way to be mechanically connected but galvanically isolated from the electrically connected cylindrical sensor body 1 and conductive end pieces 5. The transmission conductor 10 further includes end piece cable clamps 20 or other means for clamping the sensor 100 in line with a power line conductor and operable to allow mechanical and electrical connection in a power transmission line system. It is appreciated that the transmission conductor 10 and cable clamps 20 are sized appropriately for the line current, tension, and interfacing requirements of a particular transmission line installation. Inclusion of strategically located and sized conductive toroidal corona rings 30 may prevent unwanted corona discharge in areas where small radius of curvatures dictate their placement. The size of the corona rings 30 is determined by the transmission line operating voltages and they are typically included at transmission line voltages over approximately 100 KV ac. These toroidal corona 30 are in galvanic and mechanical contact with the cylindrical sensor body 1 and conductive end pieces 5 and apart from their corona reducing effect, provide additional body capacitance.

Additional corona shields 35 may be fitted on the two ends of the transmission conductor 10. It is appreciated that the general geometry of the complete sensor body is not limited to the cylindrical shape described but may be of other shapes. It will be appreciated that body capacitance is a function of shape as well as surface area and the preferable shape for a given application is dictated primarily by the AC line operating voltages and spacing requirements. A completely spherical metallic sensor body may be employed with similar performance without departing from the general operation as described.

[0022] Transformer T1 36 has a primary connection with Np turns connected between the transmission conductor 10 and the cylindrical sensor body 1. The cylindrical sensor body 1 is galvanically connected to the conductive end pieces 5 and toroidal corona shields 30. It is appreciated that the transmission conductor 10 is electrically isolated from the rest of the sensor body through the insulator bushings 15 and that the transmission conductor 10 operates at high AC voltage levels with respect to Earth ground. A small AC current Ip 37 flows through the primary winding into the cylindrical sensor body 1 as the result of the total body capacitance of the complete sensor body and the high voltage on the transmission conductor 10. A typical high AC line voltage value would range from 10 KV to over 1000 KV AC with a typical transmission line value used for this discussion of 230 KV AC line to line (three phase) or 132.8 KV AC line to Earth. The body capacitance, with respect to the Earth surface at transmission line heights is in the pico farad range with with a typical value for this discussion being 50 pF. The geometry of the sensor body, combined with the sensor height above the Earth ground plane and the proximity of other conductors such as towers and other transmission conductors (other phase conductors) combine to determine the exact body capacitance. It is important to note that the exact body capacitance is not important provided that it is high enough to establish a sufficient operating current Ip 37 and that the reflected load impedance as presented at the primary of transformer T1 36 due to power supply loading is of high enough value to allow sufficient voltage division across the primary winding and effective body capacitance series connection.

[0023] The magnitude of primary current Ip 37 is determined by the transmission line voltage applied to the transmission conductor 10 and the reactive impedance of the total body capacitance at the particular line frequency (typically 50 or 60 Hz for most

transmission lines deployed throughout the world) employed. For illustrative purposes, a body capacitance of 50 pF translates to a reactive impedance of 53 Megohms at 60 Hz. This results in a reactive primary current Ip (37) of 132.8 Kvac/53e6 equaling 2.5 mA RMS. The potential difference developed across the primary of transformer T1 36 is small in relation to the transmission conductor 10 potential (> 132 Kvac) with respect to Earth ground and may be neglected in the calculation of primary current Ip 37 flow.

[0024] Transformer T1 36 may be constructed of tape wound toroidal design and may employ very low-loss core materials in order to reduce primary magnetization currents to levels significantly below the available driving primary current Ip 37 in order to achieve usable transformer action. It may also be designed with inter-winding capacitances kept to minimal levels. Transformer T1 36 functions as a step down transformer where the ratio of Np/Ns is greater than 1. As an example, a turns ratio of 80 is used but it is appreciated that other turns ratios may be employed. Primary current Ip 37 induces a secondary current, Is 40 that is rectified through diode bridge DB1 42 and charges energy storage capacitor C1 44. The negative output of diode bridge DB1 42 is connected to system ground 43, which is galvanically bonded to the shielded electronics housing 60. This forms the "system" ground for all electronic circuitry. In this manner the transmission conductor 10 maintains a voltage differential with respect to the cylindrical sensor body 1 equal to the primary winding voltage developed across transformer T1 36. Capacitor C1 44 voltage builds up to a level of +12Vdc at which point the secondary zener diodes D1 and D2 41 clamp the secondary voltage to provide shunt regulation of the low voltage (+12 Vdc) output 45. The zener diode 41 clamping action limits transformer T1 36 secondary voltage to approximately 15 volts peak-to-peak. Transformer T1 36, through turns ratio Np/Ns transforms the clamped secondary voltage to approximately 1200 volts peak-to-peak at the primary winding. In this manner the high primary voltage of transformer T1 36, combined with low primary current, is converted to a low voltage at higher current operable to energize sensor electronics.

[0025] Inverter / Switcher block 46 provides multiple outputs required by sensor electronics. It operates from the single, 12 Vdc 45 power supply output. It is appreciated that other voltage levels and combinations may be required for particular sensing applications without departing from the spirit of the invention. It is also appreciated that

other secondary windings and rectifier circuitry could be added to transformer T1 36 in order to reduce the dependency on electronic voltage conversion circuitry.

[0026] A Gas Discharge Tube 50 may be provided to limit the primary voltage of transformer T1 36 under transient line conditions due to possible lightning strikes or other short duration line events. The Gas Discharge Tube 50 is characterized by having low inter-electrode capacitance (typ 1 pF), which is advantageous in order to prevent the diversion of body capacitive current from the transformer primary winding.

[0027] A current sensor 65 is shown coupled to the transmission conductor 10. The current sensor ideally has wide dynamic range covering from 100 mA RMS to over 2000 Arms (in the example although many other current ranges are possible). Suitable current sensing topologies include traditional toroidal magnetic core types, actively compensated types (active CTs), hall effect, optical CTs, and Rogoski coils with each having certain advantages including accuracy, cost, weight, dynamic range, and useable bandwidth. An actively compensated core type may be employed when the highest accuracy is required for revenue applications. A Rogoski coil may be employed when a high current dynamic range and/or high bandwidth is required for certain protective applications. The output of the current sensor is an analog signal that may require amplification and signal conditioning performed by the Analog circuitry 66. This module may include selectable analog gain blocks under auto-ranging processor control. The analog output of the Analog circuitry 66 may be connected to the Alias Filter and A/D module 67 which removes frequency components above ½ the sampling or Nyquist rate. The A/D converter digitizes the analog signal at the sample rate (for example 256 samples / second) and provides the digital information to the Processor module 68. The Processor Module 68 controls the Analog circuitry 66 and Alias Filter A/D Conversion 67 modules while processing and packetizing the A/D samples stream. The Processor Module 68 communicates with the RF Link Transceiver 69, which is used to transmit the acquired current waveform to the coupled ground based receiver (not shown) where the waveform is processed for power measurement or power quality information. The RF Link Transceiver 69 may operate at VHF and higher frequencies and employ a robust modulation and error correction method to provide reliable and secure telemetry data.

[0028] The RF Link Transceiver 69 is coupled to the Antenna 76 through a reactive matching network 75 formed from L1 and C2. The purpose of matching network 75 is to effectively impedance match the output of the RF Link Transceiver 69 to the Antenna 76 and maintain the DC or low frequency potential of the exposed antenna 76 at the potential of the shielded electronics housing 60. Other L, C, and transformer matching circuitry may be used to achieve similar functionality. The circuitry shown 75 is essentially a high pass filter with inductor L1 75 maintaining the zero DC and low frequency (50/60 Hz) potential of the antenna 76 with respect to the shielded electronics housing 60 common potential.

[0029] Sensor body 1 may be split vertically into two separate sections that are insulated from one another. The first section may be used as previously described to derive operating power for the device. The second section may be used to sense the voltage on the transmission conductor 10 by monitoring current flow from the transmission conductor 10 to the body capacitance of the second section. A second transducer may thus be provided to supply an analog signal indicative of voltage in transmission conductor to analog circuitry 66. In this manner, processor 68 may directly calculate power parameters such as watts flowing through the transmission conductor due to the local availability of both current and voltage information before transmitting the data.

[0030] Additional transducers may also be interfaced to processor 68 and powered by inverter/switcher block 46. These additional transducers may include vibration, tension, temperature (both for the conductor and ambient temperature), lightning detector and other types of transducers.

[0031] Instead of using an RF Link Transceiver 69, an RF transmitter may be used. In addition, the RF Link Transceiver 69 may be replaced with a laser data transceiver or transmitter. This has the advantage of being extremely directional and therefore it is much more difficult to jam or tamper with the signal. RF has the advantage of being less susceptible to obstructions such as airborne particulates, fog, or objects physically blocking the signal.

[0032] Processor 68 may be equipped with an accurate time base. This time base may come from the RF transceiver or may come from a separate time source such as a GPS

transceiver. This allows the processor 68 to accurately timestamp the time of the A/D conversion data to be transmitted. This allows the accurate computation of power parameters (such as kW, kVAR, kVA, power factor, symmetrical components, etc.) by the ground based transceiver or computer/intelligent electronic device attached thereto. A GPS transceiver may also provide the location of the sensor 100 to the processor 68. This may include the elevation of the sensor which may be useful in detecting transmission line sag due to broken insulators, overheated conductors, etc.

[0033] Sensor 100 may be constructed in "clamp-on" form. In this case, transmission conductor 10 is the transmission line of a power system. Sensor body 1 is constructed in a manner operable to split horizontally as oriented in Fig. 1 and may be placed over the transmission line and clamped together. In this case, cable clamps 20 and additional corona shields 35 may not be provided.

[0034] It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the spirit and scope of this invention.

WE CLAIM:

A1. A sensor for monitoring a parameter related to a high voltage power line comprising:

a metallic body operable to surround said power line;

a coupling between said metallic body and said power line operable to maintain said metallic body and power line in a spaced relationship;

a power supply comprising current supply and return paths;

a transducer operative to sense said parameter and generate an analog signal indicative of said parameter;

an analog to digital converter operative to convert said analog signal to a digital signal indicative thereof;

a processor coupled to said analog to digital converter;

a wireless transmitter coupled to said processor and operative to transmit data indicative of said digital signal;

wherein an output of said power supply powers at least one of said transducer, analog to digital converter and processor; and

further wherein at least one of said current supply and return paths is coupled to said metallic body and the other of said current supply and return paths is coupleable to said power line; said power supply being powered by the flow of current from said power line, through said power supply and the body capacitance of said metallic body.

A2. The sensor of claim A1 wherein said power line comprises a transmission line and said sensor is clampable around said transmission line.

A3. The sensor of claim A1 further comprising:

cable clamps disposed on first and second ends of said power line and wherein said sensor is operable to be installed in line with a transmission line conductor by coupling to said cable clamps.

A4. The sensor of claim A1 wherein said parameter is ambient temperature.

A5. The sensor of claim A1 wherein said parameter is temperature of said power line.

A6. The sensor of claim A1 further comprising a second transducer operative to sense a second parameter and generate a second analog signal indicative of said second parameter; wherein said analog to digital converter is operative to convert said second analog signal to a second digital signal indicative thereof.

A7. The sensor of claim A6 further comprising:

a second metallic body adjacent to said first metallic body and insulated from said first metallic body; wherein said second transducer is operative to measure a second flow of current from said power line to said second metallic body through a known impedance; said second flow of current indicative of the voltage on said power line.

A8. The sensor of claim A1 wherein said parameter is tension in said power line.

A9. The sensor of claim A1 wherein said parameter is elevation of said power line.

A10. The sensor of claim A1 wherein said parameter is wind speed proximate said sensor.

A11. The sensor of claim A1 wherein said parameter is vibration.

A12. The sensor of claim A1 wherein said wireless transmitter is an RF transmitter.

A13. The sensor of claim A1 wherein said wireless transmitter is a laser.

B1. A sensor for monitoring a current in a high voltage power line comprising:

a metallic body operable to surround said power line;

a coupling between said metallic body and said power line operable to maintain said metallic body and power line in a spaced relationship;

a power supply comprising current supply and return paths;

a transducer operative to sense said current and generate an analog signal indicative of said current;

an analog to digital converter operative to convert said analog signal to a digital signal indicative thereof;

a processor coupled to said analog to digital converter;

a wireless transmitter coupled to said processor and operative to transmit data indicative of said digital signal;

wherein an output of said power supply powers at least one of said transducer, analog to digital converter and processor; and

further wherein at least one of said current supply and return paths is coupled to said metallic body and the other of said current supply and return paths is coupleable to said power line; said power supply being powered by the flow of current from said power line, through said power supply and the body capacitance of said metallic body.

B2. The sensor of claim B1 wherein said transducer comprises an active current transformer.

B3. The sensor of claim B1 wherein said transducer comprises a current transformer.

B4. The sensor of claim B1 wherein said transducer comprises a Rogowski coil.

B5. The sensor of claim B1 wherein said transducer comprises an optical current transformer.

B6. The sensor of claim B1 wherein said transducer comprises a Hall effect sensor.

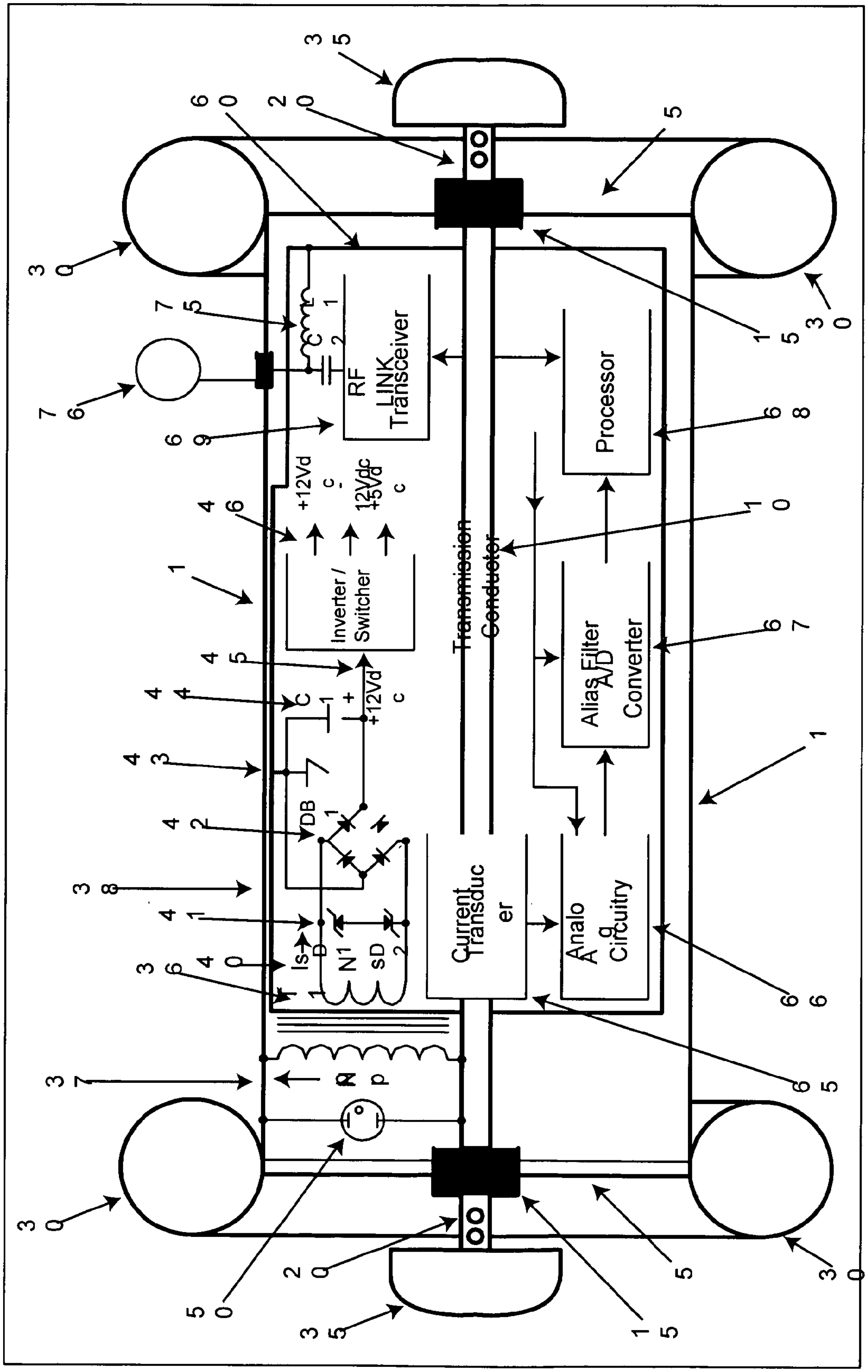
100
RF LINK Transceiver
Processor
Inverter / Switcher
Alias Filter A/D Converter
Transmission Conductor
Current Transducer
Analog Circuitry
+12Vdc
+5Vdc

Figure 1